J. Pure Appl. & Ind. Phys. Vol.3 (2), 88-92 (2013)

Study of Electrical Resistivity of Beryllium

SANJAY KUMAR[1], ANIL KUMAR BARNWAL[2], and PURUSHOTTAM PODDAR.*

*Department of Physics,
Magadh University, BodhGaya, INDIA.
[1]St. Xavier's College, Ranchi, INDIA.
[2]Adarsh College Rajdhanwar, VBU Hazaribag, INDIA.

(Received on: January 28, 2013)

ABSTRACT

In this paper we have analysed the electrical resistivity of two different specimen of Be. Both specimen display a relatively high residual resistance. In both cases the ideal resistivity is very small. The behaviour of electrical resistivity of Be is strongly suggestive of impurity semiconductor properties and concords with the fact that the soft x-rays emission spectrum behaves as though the levels of a single zone almost completely occupied indicating that this metal is very nearly an insulator. From the analysis of reported data we have got two contradictory results, viz, metallic character and semiconducting character. Finally we got Be behaves as semiconductor at low temperatures and when temperature increases it behaves normal metallic character at high temperatures.

Keywords: Electrical resistivity, Residual resistance, Semi-conductor, Insulator, conductivity, Ideal resistivity.

1. INTRODUCTION

Beryllium has attracted a lot of theoretical and experimental interest because of its simple atomic electronic configuration and anomalous physical properties. The crystal structure is hexagonal close packed with only two valence electrons per atom. The Debye temperature is very high[1] (1440K) compared with close neighbors in the periodic table, e.g., lithium (344K) and magnesium (400K). The metal is unique in the respect that it has the highest velocity of sound of any metal (because of a combination of low density and large elastic constants). Its two valence electrons should fill the first Brillouin Zone, and therefore beryllium should be an insulator. Indeed, Seitz[2] has pointed out that soft x-ray studies indicate a nearly filled first zone. However,

beryllium is a good conductor, being only four times worse than copper at room temperature. Two effects contribute to this high conductivity. First, band- structure calculations[3] indicate that there is overlap of the electrons into the second and higher zones, and second, because of the relatively strong elastic forces binding the light beryllium atoms,[4] the amplitude of atomic vibration and, hence, electron-phonon scattering is relatively less.

The temperature dependence of the resistivity is difficult to interpret because of the high Debye temperature and the anisotropy of the resistivity, especially since the single-crystal measurements have not yet been extended through the Debye temperature to the melting point.

2. THEORETICAL DISCUSSION

Experimentally observed values of the electrical resistivity of Beryllium, below 300K reported by Mac Donald & Mendelssohn[5] are listed in Table 1-2. Its behaviour with temperature is shown in figure 2. The results of (R/R_{273}) for Be_1 and $Be_{(2a)}$ are shown in Table 1. Be_1 and $Be_{(2a)}$ are two different speciment of Be. Values of (R/R_{273}) for those specimen have been taken from the literatures[6-9]. In both cases the resistance ratio is effectively constant in the region below 20K. Both specimen display a relatively high residual resistance. In the specimen Be_1 the resistance is practically constant in the temperature interval from 4.2 to 90K. In both cases the ideal resistivity is very small. Similar behaviour of resistance of two other specimen of beryllium is reported by Meissner and voigt[10] and Mitchell[9]. This behaviour of electrical resistivity of beryllium is strongly suggestive of impurity semiconductor properties and concords with the fact that soft x-rays emission spectrum behaves as though the levels of a single zone almost completely occupied indicating that this metal is very nearly an insulator. Table 2 shows the values of ideal resistance ratio (r) of third specimen of Be $_{(2b)}$[5].Where r= (R_1/R_{290K}), R_1 is the ideal resistance. θ of Be lies between 1100 and 1160K, from specific heat measurement[11-13]. The values of r in Table 2 lie between 43 and 76K. The temperature zone is suitable for the application of Bloch- T^5 law. To verify this law in $Be_{(2b)}$, we have plotted logr against log T. The plot is a straight line curve shown in Fig. 1. The slope and intercept of the curve has been obtained by the least square method. The equation fit to the curve, so obtained is written as,

$$\text{Log } r = -10.2716 + 4.6438 \log T \quad [43 \leq T \leq 76] \qquad (1)$$

Which gives

$$r = 5.195173 \times 10^{-11}\, T^{4.6438} \qquad (2)$$

Equation (2) leads to

$$\rho_T(i) \propto T^n \qquad (3)$$

Where n= 4.6438, ρ_T (i) stands for ideal electrical resistivity at temperature T. The Bloch-T^5 law is not exactly true but the value of n is close to 5. The interecpt of the curve log r against log T gives the values of log (497.6/290) ($1/\theta^4$). The intercept of the curve [cf. equation (1)] has been used to calculate the value of θ. The calculated value of θ is found to be 426.2K. It is much smaller than either 1100 or 1160 K obtained from the specific heat measurements.

Further we have plotted r[cf. Table 2} against temperature T, the plot is again a straight line curve between 52 and 76 K shown in Fig. 2. The least square equation fitting in the data of 'r', so obtained, is

$$r = -0.02737 + 6.4912X10^{-4}T \quad (4)$$
$$\gamma = 0.990$$

The temperature dependences of 'r' in equations (2) and (4) differ from each other. The former gives $r \propto T^{4.6438}$ and later gives $r \propto T$. These two equations of 'r' are equally good. The calculated values of 'r' from equation (2) and (4) are also shown in Table 2. These result makes the matter complicated. The equation (2) favours the validity of T^5 -law and hence that of free-electron model. However, equation (4) goes against the above conclusion. The behaviour of electrical resistance of specimen Be_1 and $Be_{(2a)}$ [cf. Table 1] with temperature favours the conclusion of equation (4). The simultaneously two contradictory results, viz. metallic character and semiconducting character predicted by equations (2) and (4) make a confusion in the property of beryllium. This confusion is removed by the temperature behaviour of the electrical reisistivity of beryllium in Table-3, Figure (3).

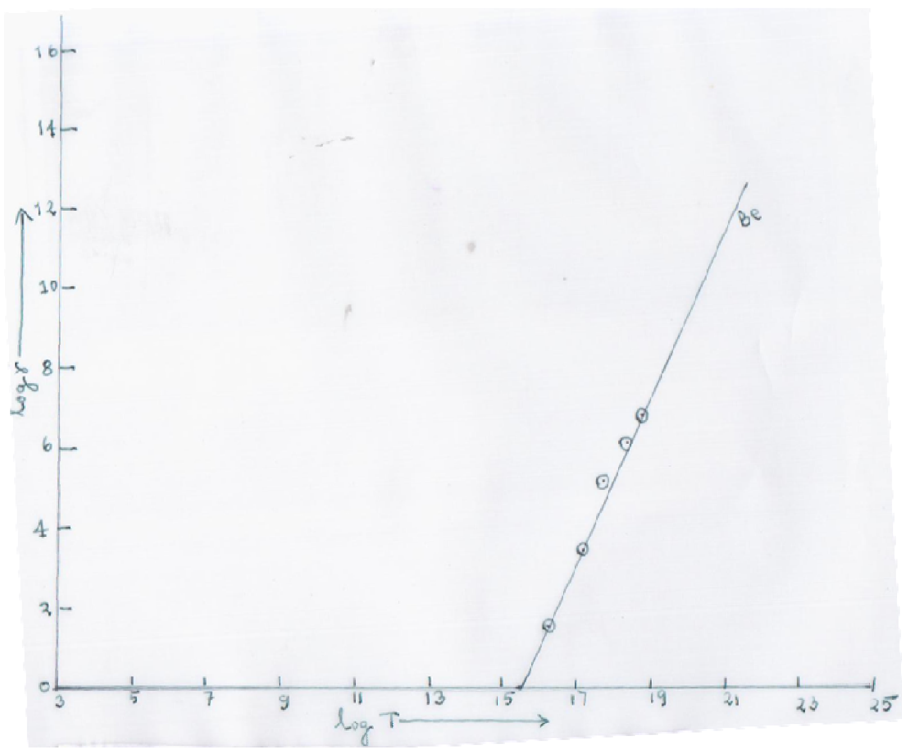

Fig.(1) : Plots between long (r) and log (T) (The scales and origin have been suitable by altered to portray the desired shape of the curve)

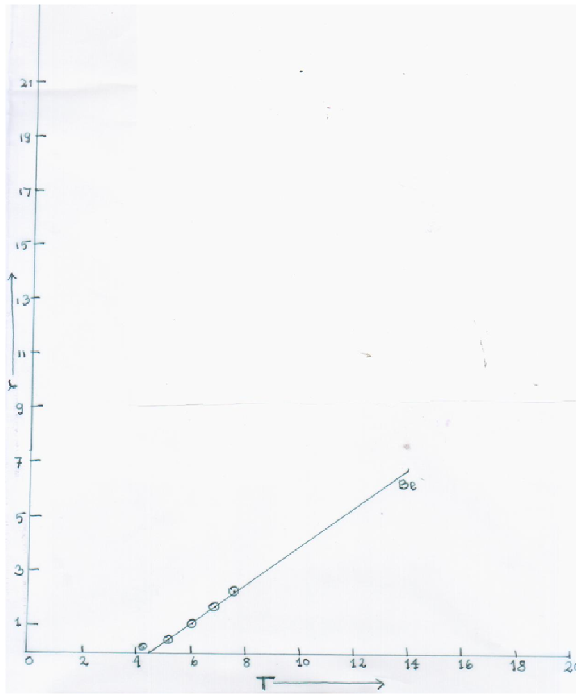

Fig. (2) : Dependence o electrical resistivity ratio (r) on temperature (T) (The origin and the magnification scales along the axes have been suitably altered to present just the desired shape of the curve)

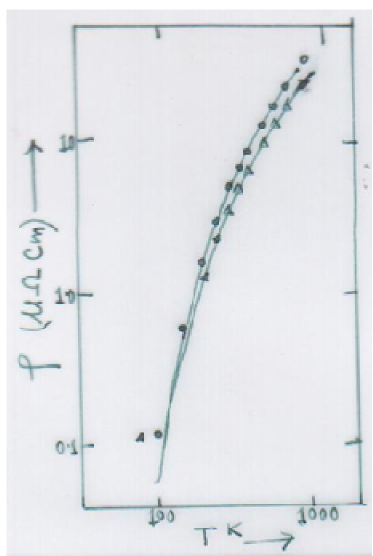

Fig. (3) : Temperature-dependent electrical resistivity of beryllium. The data points are the constant pressure resistivity corrected to constant volume.

Table-1: Electrical resistance ratio of two specimen of Be

T^K	$Be_1(R/R_{273K})$	$Be_{(2a)}$ (R/R_{273K})
273	1.00	1.00
90	0.39	0.32
20.4	0.38	0.27
4.2	0.38	0.27

Table-2: Ideal resistance of a specimen of Be

T^K	r_{obs}	r_{cal}. from eqn.(2)	r_{cal}.from eqn. (4)
43.0	0.002	0.002	0.00054
52.0	0.005	0.0048	0.0064
60.4	0.011	0.0097	0.0118
68.8	0.017	0.0177	0.0173
76.0	0.023	0.028	0.0219
290.0	1.000	-	-

Table-3: Resistivity (constant pressure) of single crystals of Be[9]

T^K	(μΩcm)	
	ρ_1	ρ_2
10	0.41	0.19
50	0.41	0.19
100	0.53	0.31
150	1.00	0.73
200	2.00	1.45
250	3.35	2.45
300	5.10	3.67
350	6.90	5.00
400	8.70	6.40
500	12.70	9.40
600	17.10	12.63
700	21.90	16.03
800	27.10	19.70
900	33.20	23.90

3. CONCLUSION

We find that beryllium is not of uniform metallic character throughout the temperature zone, rather their behaviour varies from semiconductor to metal as the temperature increases from the lowest value.

REFERENCES

1. American Institute of Physics Hand book, 3rd ed., Mc Graw- Hill, New York, Tables 4e-10 and 7b-1 (1972).
2. F. Seitz, Modern Theory of Solids, Mc Graw-Hill, New York, P. 439 (1940).
3. T.L. Loucks and P.H. Cutler, *Phys. Rev.* 133, A 819 (1964).
4. K.H. Schramm, Z. Metallk. 53, 729 (1962).
5. D.K.C. Mac Donald and K. Mendelsohn, *Proc. R. Soc.* A 202, 523 (1950).
6. Boorse *et. al*. *Proc. Roy. Soc*. A, 153 463 (1936)
7. Gorter, *Physica*, 5, 483 (1938).
8. Lane, *Phys. Rev*. 76, 304 (1949).
9. Mitchell, M.A., *J. Appl. Phys*. 46 2011, 4742 (1975).
10. Meissner, A.D. & Voigt, *Ann. d. Phys*. (5) 7, 761 & 892 (1930).
11. Thermo Phsical properties of Matter, Vol. 4 (1972).
12. Simon, F. & Cristescu, S. Z. *Phys. Chem*. (B) 25; 273 (1934).
13. Purushottam Poddar and Anil Kumar Barnwal, *J. Pure Appl. & Ind. Phys*. Vol.2. (3), 242 (2012).